

Title	STUDIES ON THE CIRRIPEDIA ACROTHORACICA -I. BIOLOGY AND EXTERNAL MORPHOLOGY OF THE FEMALE OF BERNDTIA PURPUREA UTINOMI-
Author(s)	Utinomi, Huzio
Citation	PUBLICATIONS OF THE SETO MARINE BIOLOGICAL LABORATORY (1957), 6(1): 1-26
Issue Date	1957-06-30
URL	http://hdl.handle.net/2433/174576
Right	
Type	Departmental Bulletin Paper
Textversion	publisher

STUDIES ON THE CIRRIPEDIA ACROTHORACICA

I. BIOLOGY AND EXTERNAL MORPHOLOGY OF THE FEMALE OF *BERNDTIA PURPUREA* UTINOMI¹⁾

HUZIO UTINOMI

Seto Marine Biological Laboratory, Sirahama

With Plates I-II and 11 Text-figures

CONTENTS

	Page
INTRODUCTION	1
ACKNOWLEDGMENT	2
MATERIAL AND METHOD	2
NATURAL HABITAT AND DISTRIBUTION	3
Natural Habitat	3
Distribution	4
EXTERNAL MORPHOLOGY OF FEMALE	6
Mantle and its Derivatives	6
Body and its Segmentation	12
Oral cone and Mouth-parts	15
Cirri	17
CIRRAL MOVEMENT AND FEEDING HABIT	19
SUMMARY	23
REFERENCES	24
EXPLANATION OF PLATES I-II	26
LIST OF ABBREVIATIONS USED IN THE TEXT-FIGURES	26

Introduction

About twenty years ago, while examining reef corals occurring in Tanabe Bay on the Pacific coast of southern Japan, I happened to find an Acrothoracian cirriped plentifully boring into the two kinds of reef corals, and reported its find, only mentioning about its close affinity with *Lithoglyptes indicus* AURIVILLIUS which was hitherto known as an Acrothoracian boring in corals and molluscan shells, though characterized by some remarkable peculiarities (HIRO, 1937). Since then I have continued the studies on this Acrothoracian, though so much interrupted by my military service of three years during the war, and, as a matter of fact, major part

1) Contributions from the Seto Marine Biological Laboratory, No. 291.

of them have hitherto been finished in 1943. After the war, in a short preliminary note (UTINOMI, 1950a, c), I described it for the first time under the name *Berndtia purpurea* n. gen. et sp. In addition to this, another new Acrothoracican *Balanodytes taiwanus* n. gen. et sp. from Taiwan was also described (UTINOMI, 1950b, c).

In a series under the head title I will give hereafter the detailed descriptions of these two forms, and additionally intend to contribute some new informations regarding the comparative anatomy, homology and classification in the Acrothoracica. The present paper given here is the first part of this series dealing with the biology and external morphology of the female of *Berndtia purpurea*.

Acknowledgment

Before proceeding further I wish to acknowledge my indebtedness to many persons who have supported the present investigation in various ways. In particular, I am greatly indebted to the late Yanosuke SAIKA, who was an eminent collector and skipper served over a period of thirty years at our Seto Laboratory and died on February 10th, 1957, aged 69, for assistance at the field works and in collecting the material by diving. I wish to express my sincere thanks to Prof. Emeritus Taku KOMAI of Kyoto University for his kind guidance and encouragement throughout the work. Further thanks should be extended to Prof. Emeritus Hisakatsu YABE, the late Dr. Toshio SUGIYAMA and Dr. Motoki EGUCHI for allowing me to examine the vast collections of reef corals deposited in the Museum of the Paleontological and Geological Institute of Tôhoku University at Sendai.

Material and Method

The material of the present Acrothoracican *Berndtia purpurea* was obtained in the littoral of Tanabe Bay at any occasion throughout this work.

For systematic purposes, some specimens were selected as type specimens (Type No. 53) to be preserved in the collections of the Seto Marine Biological Laboratory. Additional specimens (Rare Nos. 94 and 103) are also preserved as they are associated with their host corals.

Living animals were observed in the sea, or, after transferred from the natural habitat, in the aquaria without removing from the coral colony. Observations on the cirral movement and the larval development were made by placing the infected coral stock in a large flat-bottomed dish containing sea water. Dissection of living and fixed materials was made under the binocular microscope by means of fine and sharp needles. For microscopical study of the detailed internal structures which will be dealt with in Part II, serial sections were made, and some drawings in this paper were made by using the method of projection reconstruction.

All the materials for microscopical examination were fixed with 3% formalin, Bouin's solution or Rabl's picro-sublimate solution all of which brought good results

in the same way. The microtome sections were stained with the usual methods of Delafield's or Ehrlich's haematoxyline-eosin and boraxcarmin-bleu de Lyon, and also, for the male, with boraxcarmin, acetocarmine or methylen-blue alone.

Natural Habitat and Distribution

Natural Habitat

All the species of the Acrothoracica are known to live buried in the calcareous matter such as certain chitons, gastropod shells, barnacle plates and corals. The present Acrothoracican is found in abundance, invariably bored into the living colonies of the two kinds of corals, *Leptastrea purpurea* (DANA) and *Psammocora profundacella* GARDINER, both common on submerged cliffs or reefs just below the lowest tide level around the Laboratory. The frequency of occurrence seems to be greater in *Psammocora* than in *Leptastrea*, probably because of the smaller calices and thinner coenosarc covering the hard skeleton. In both corals it diminishes as the habitat becomes deeper. As an example of greatest infection I have met with, about 150 individuals were found in an area of a square 5 centimeters on a flat surface of *Psammocora profundacella* colony.

In the neighboring places some different corals are usually found in association with them. However, curiously enough there is no trace of infection of the Acrothoracican. This fact shows that the association between Acrothoracican and corals aforesaid is by no means incidental but obligatory for survival in the former. Apparently the permanent occurrence on the coral is not harmful to the life of the latter, but their heavy infection seems to be subject to more or less modification of calices around the infected part in size or manner of growth.

In an example of *Psammocora* heavily infected by this Acrothoracican, the calices are usually smaller with less numerous septa and separated by broader interspaces of coenosarc than in the uninjured specimen. Such specimen, as far as the structure of calices is concerned, is apparently a separate species (cf. YABE et al., 1936, p. 61, pl. XLIV, fig. 7 and pl. XLV, fig. 9). In my opinion it may be a deformed specimen of ordinary *P. profundacella* due to the dense infection of Acrothoracicans, especially in view of its rigid host specificity. In fact, I have often observed that the lodgment of other coral-inhabiting barnacles, such as *Creusia* and *Pyrgoma*, is subject to modify the direction of growth of the host coral to some extent accompanying with the repair growth of the latter itself (HIRO, 1938).

The occurrence of *Berndtia purpurea* is readily defined by its peculiar oblong slit of the burrows, as is shown in Plate I. In any colony of the infected corals, the situation of these slits is always confined to the living part of the coral and none is found on the dead part; but if present, they may possibly be those formed before the corals have died. As a rule the slits are situated on the skeletal wall between calices, because the animals settle on the coenosarc between polyps at their early stage

of excavation. Therefore, the animals fastened themselves to the coral skeleton are able to excavate downwards and to reach to a full size with the least trouble as the polyps of infected corals grow upwards. As to the function of excavation connected with the larval development, this will be discussed in a later paper.

The slit is oblong in outline and a little more rounded on one end (namely the rostral side of the animal) than on the other (namely the carinal side). It measures about 1 to 3 mm in length and 0.3 to 1.2 mm in width. The edge of the slit is slightly ridged and whitish, and the space in the slit is often filled with calcareous matter which consists of fine granules and silt or detritus, discharged by its own function of excavation and entangled with mucus secreted from the coral. If such slimy calcareous granules are excessively deposited at the slit and cover wholly the opening, it may be dangerous to the enclosed animal. However, the opening of the burrow is incessantly swept by the cirral movement, so that it may not be so dangerous as would be expected.

Distribution

From the above fact that the association of *Berndtia purpurea* with the two particular kinds of corals is very rigid in examples of Tanabe Bay, it is very likely that it may occur more widely in tropical seas.

Fortunately enough, I have had the opportunity of examining the extensive collection of reef corals preserved in the Museum of the Institute of Geology and Paleontology, Tôhoku University at Sendai, through the kindness of the authorities of that Institute in charge of the coral collection. The collection has been gathered from various localities of Japan, Micronesia and other all tropical seas, and based on this collection three monographs with magnificent photographs have been published by that University in 1936, 1941 and 1942 respectively.

On examination I have ascertained again that the infection of *Berndtia purpurea* is strictly confined to the two corals mentioned above. The localities of the examined specimens of corals apparently infected by *Berndtia*, as inferred from the peculiar slits, are given below, with details of registered numbers. Some of them are finely illustrated in the first volume of the aforementioned monographs (YABE, SUGIYAMA and EGUCHI, 1936).

Leptastrea purpurea (DANA)

- 1) Tanabe Bay, Wakayama-ken, Honsyû. (Reg. No. 40525, etc.)
- 2) Muroto-zaki, Kôti-ken, Sikoku. (Reg. No. 40770)
- 3) Suzuki, Kôti-ken, Sikoku.
- 4) Ōura, Miyazaki-ken, Kyûsyû. (Reg. No. 40773)
- 5) Konesime, Kagoshima-ken, Kyûsyû. (Reg. No. 40775)
- 6) Naka-kosiki, Kosiki Islands, Kagoshima-ken, Kyûsyû. (Reg. No. 48263)
- 7) Usibuka, Kumamoto-ken, Kyûsyû. (Reg. No. 45147)

- 8) Hükikaku, Northernmost end of Taiwan. ? damaged.
- 9) Helen Reef, Palau Islands, Micronesia.

Psammocora profundacella GARDINER

- 1) Tanabe Bay, Wakayame-ken, Honshū. (Reg. No. 36886)
- 2) Kusimoto, Wakayama-ken, Honshū. (Reg. No. 40974)
- 3) Suzaki, Kōti-ken, Sikoku. (Reg. No. 36887)
- 4) Sarusima, Miyazaki-ken, Kyūshū. (Reg. No. 36885)
- 5) Udo, Miyazaki-ken, Kyūshū. (Reg. No. 40983)

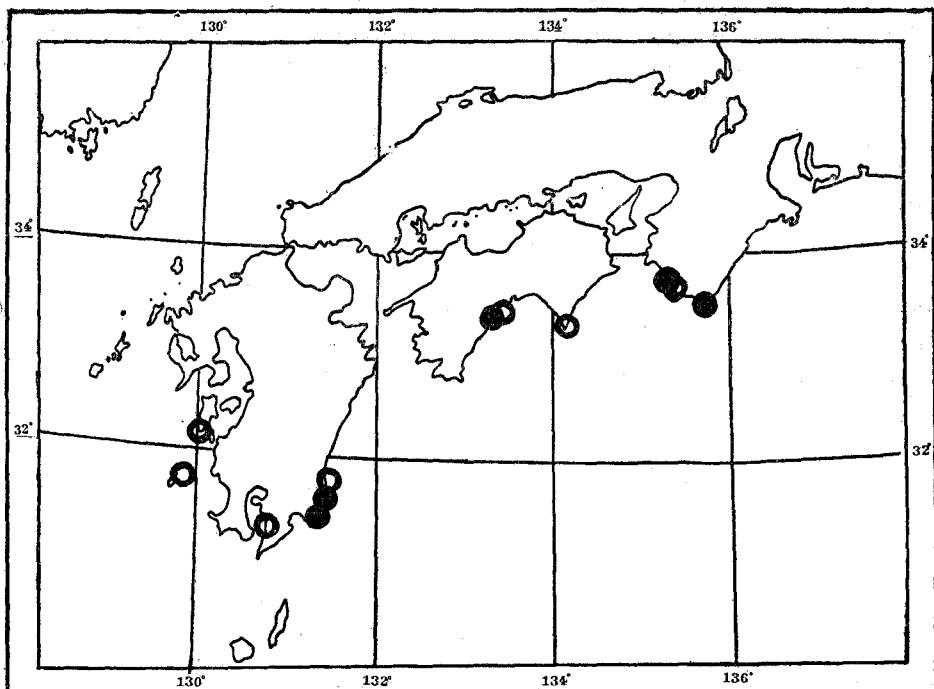


Fig. 1. Distribution of *Berndtia purpurea* on southern coast of Japan, as deduced from the localities of infected reef corals.

- *Leptastrea purpurea* (DANA).
- *Psammocora profundacella* GARDINER.

From these collecting records of the corals, it may be concluded that the actual center of distribution of *Berndtia purpurea* is the Pacific coast of southern Japan as far north as Tanabe Bay where is the type locality (Fig. 1). It may range further southwards, for it occurs on specimens from Taiwan and Helen Reef of Palau Islands, though being only one case respectively.

Whereas many specimens of the same species and related species belonging to the same genera from Taiwan, Micronesia and Australasian Archipelagoes were likewise examined, I found in vain. And also during a stay at Palau during the year

1934-35 I was engaged in collecting corals and studying the animal associated with them. But I could not find any species of the Acrothoracica on corals.

Nevertheless, there is an only exceptional case which I have encountered in consulting with literature and photographs of reef corals on hand. That is a specimen of Fungiid coral *Podabacia crustacea* (PALLAS) from Singapore which is illustrated in Plate 67, fig. 1 of MA's paper (1937); namely, from his photograph we find that the under surface of the colony concerned was heavily infected with an Acrothoracican species, probably referred to this *Berndtia*, or else an unknown species. The original specimen of this coral is probably housed in the Museum of the National Research Institute of China at Nanking, with Reg. No. 469, and cannot be examined directly in detail. It is thus uncertain whether the infected Acrothoracican is truly *Berndtia* or *Lithoglyptes* or other form, and whether the infection is no more than incidental or else ordinary as in the above case.

Anyhow, excepting those taken from southern Japan, the infected materials (or photographs) of the corals so far examined are too poor to allow any positive conclusion concerning the actual distributional range of the present Acrothoracican. Most probably future investigations will reveal new localities or new hosts if larger material of reef corals from tropical seas is carefully examined. This is, however, a tedious task, and it is to be hoped that all workers dealing with reef corals will pay more attention to the possible occurrence of Acrothoracicans or their corresponding burrows and record their finds.

External Morphology of Female

Mantle and its Derivatives

GENERAL SCHEME. The animal adheres quite firmly to the wall of its burrow by a part of the mantle, named the 'attachment-disc'. Hence it can be freed from the coral by breaking the coral wall or by placing the infected coral block in a dilute solution of hydrochloric acid in 70% alcohol for a few days.

The mantle as a whole is shaped like a laterally compressed sac with a slit-like orifice at the tip. It is generally 3-5 mm in length, 2-4 mm in breadth dorsoventrally and 0.8-1.5 mm in thickness, the average size in breadth and thickness being not much different at the upper and lower levels. The rostral side of the mantle, which is shorter than the carinal side, is developed to a horny disc, often lengthened longitudinally. The horny disc occupies a little convex and rather narrow area between the sides of the mantle and a position oblique to the orifice or the surface of the coral; it is very rare that the disc is widened laterally so as to form such a dorsoventrally compressed plane as in *Trypetesa lampas* (HANCOCK), even if fully developed. The lower end of the disc is, when fully developed, sometimes protuberant like a knob and separated from the carinal side of the mantle by a slight fold, but this

may be due to the degree of expansion of the ovarian mass embedded under the disc.

The 'operculum' or mantle-lips formed at the tip of the mantle-sac is, as viewed from above, oblong, with a straight median slit which is the orifice leading to the mantle cavity. Its outline conforms well to the slit of the burrow in which the animal is lodged. The upper surface of the operculum is, when seen from sides, slightly concave above and lies somewhat obliquely to the axis of the mantle. Both the carinal and rostral ends are produced like a canoe-head, and separated by each a deep notch from the mantle itself.

The general outline of the mantle-sac, as mentioned above, closely resembles that of *Lithoglyptes indicus* AURIVILLIUS (1894) which is known only from the Indonesian waters and lives buried in reef corals and molluscan shells, so that I was at first inclined to refer it to the latter. By closer examination especially on the internal structure, however, it was revealed that it belongs to a different species generically distinct from *Lithoglyptes*. Judging from a figure given by him (cf. Taf. 5, fig. 18), the slit of the burrows of *L. indicus* is apparently sharply pointed and bent to either side at its rostral end. If so, it is surprising that the mantle-lips forming together the operculum closely fitted to the slit of burrows, figured by him (cf. Taf. 5, fig. 10), are bilaterally symmetrical at both ends.

COLORATION. The animal, when alive, is very beautiful and impressive for the brilliant color markings on and around the operculum. The typical color of a ripe female has been reproduced in Plate I. The color variation is not pronounced in individuals of all sizes. The operculum is, when seen from above, marked with two pairs of deep violet-blue patterns symmetrically disposed on both lips. The posterior band in each lip perfectly traverses from side to side and its margins are deeply concave anteriorly and posteriorly, while the anterior band is fungoid in outline, leaving a narrow space toward the inner edge of the orifice. In addition there is a golden and resplendent body perceptible through the epidermis in the anterior color marking on both sides, lying close to the inner edge. This is an eye embedded in the connective tissue below the operculum (Fig. 2, e). The remaining part of the operculum, except all edges being deep violet-blue, is whitish and tinged with blue dots. In any case these blue dots become indistinct or sparse anteriorly and posteriorly.

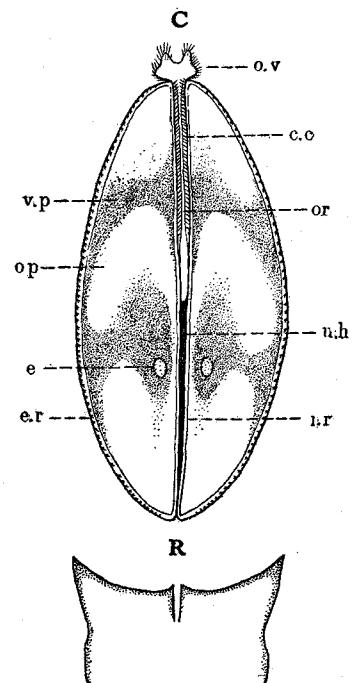


Fig. 2. Upper view of operculum (above) and its cross section through the middle portion (below). Lettering is given at the end of text (p. 26). $\times 20$.

The upper part of the lateral sides of the mantle is also tinged with a dull violet-blue to dark purple hue which becomes indistinct downwards. In addition there are three pale bluish or whitish patterns without a definite outline close to the upper margin, the locations of which correspond with those of the same colored areas on the operculum. Further downwards, the mantle-sac is colored yellowish to pinkish yellow or orange, the latter depending upon the age of the animal with growing egg-mass within the mantle-cavity (cf. Plate I, Figs. 1-3).

Internally, the ground color of the body is almost similar to that of the mantle, though much lighter in tone. The upper portion of the head is of a dull violet-blue hue as in the operculum. The posterior portion of the body, especially around the pedicels of terminal cirri, which are protruded out of the orifice, is also the same. The remaining part of the body and the rami of thoracic cirri are uniformly yellowish to pinkish orange. If put the animal into alcohol, these colors would finally fade away, though a violet hue remains for a certain period.

According to AURIVILLIUS (1894), *Lithoglyptes indicus* is whitish, tinged with an indigo-blue color around the edge of the orifice and the neighboring part of the mantle. *L. bicornis* is likewise whitish and furnished with a dark violet stripe below the orifice, whereas *L. ampulla* is whitish at all. Of the other Acrothoracicans, *Cryptophialus minutus* is purple around the orifice and labrum, while *Trypetesa* (= *Alcippe*) *lampas* is colorless or yellowish (DARWIN, 1854). Recently described *T. lateralis* is said to be yellow or orange (TOMLINSON, 1953). Thus the coloration of *Berndtia* is more allied to that of *Lithoglyptes* than to any other. Possibly a similarity in coloration may be regarded as an adaptive significance to the similar habitat.

OPERCULUM. The tip of the flattened mantle-sac, forming the so-called mantle-lips on both sides of the orifice, shows a peculiar feature most like that of *L. indicus*. The lips on both sides are perfectly shut at rest, and thus act as the operculum (Fig. 2, *op*); the term is used as homologous with that of ordinary cirri-peds, though lacking the calcareous valves. They are very thickened, hardened and chitinous on surface. When seen from above, it is oblong in outline, with a straight median slit leading to the mantle opening. Each lip is thus encircled with an outer convex and an inner straight edge; the former (*e.r*) is sharply ridged and fringed with numerous, close-set chitinous spines, while the latter (*i.r*) is slightly ridged and smooth. The upper surface between the two ridges is somewhat hollowed out and apparently smooth.

ORIFICIAL VELUM. The mantle-lips on both sides are connected at the rostral half of the orifice (*or*) and a little below the inner edge. So there is formed a narrow furrow above the upper surface of the head (*u.h*). At the carinal end of the orifice, the upper edge of the mantle between both lips forms a flexible, thin velum folded outwards, partly closing the orifice. The mantle opening, which leads to the mantle cavity, occupies only the posterior half of the slit between the lips. Thus, the

orifice can be opened and shut owing to its being hinged at the rostral or anterior end, consequently when the operculum is closed, the velum is folded outwards. Similar structure has been noticed by DARWIN in *Cryptophialus minutus*, though it is on the contrary folded inwards. This is probably homologous with the membranous lining extending inwards from the base of the carina between the two terga in the rock-burrowing barnacle *Lithotrya* (CANNON, 1947).

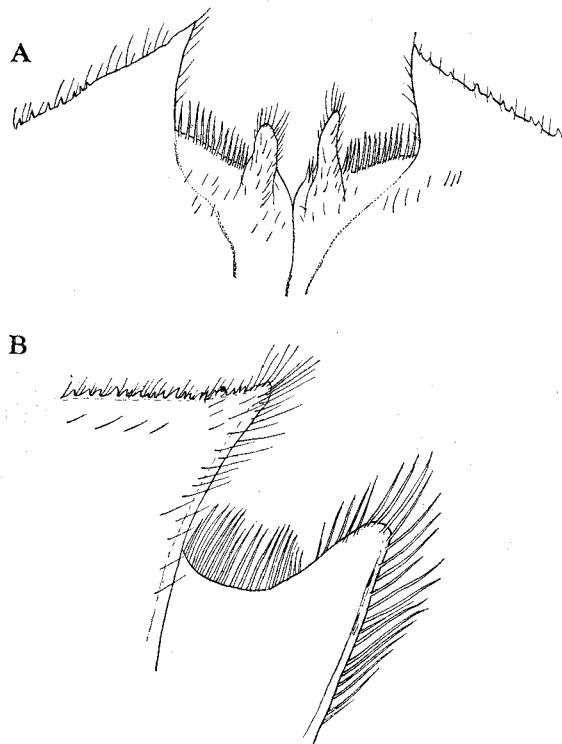


Fig. 3. Orificial velum folded outwards at the carinal end of orifice. A, inner view. B, lateral view.
×60.

This orificial velum (*o.v.*) as I here name acts like a hand-bellows each time the operculum opens and closes, and presumably concerned with the boring action which is peculiar to the Acrothoracica and *Lithotrya*. The velum is deeply notched in the middle and on each side formed a prominence thickly covered with coarse hairs. The free edges and outer surface of the velum are likewise coarsely fimbriated (Fig. 3).

COMB-COLLAR. A little way down within the orifice, the true mantle opening is fringed on either side with a comb-like row of flattened setae, which are united at their bases and roundly ended at their free ends. This is named here the 'comb-

collar' (Fig. 4, *c.c*) and extends from the orificial velum towards about half of the mantle opening, and the setae become gradually shorter inwards and finally obsolete. These setae are about 0.07–0.09 mm long. The plantation of these setae, as well as coarse hairs at the edge of the orificial velum, may possibly act as a barrier to prevent the ingress of any foreign object into the sac. This comb-collar, which is lacking in ordinary cirripeds except one genus *Ibla*, may be considered as one of the highly specialized structures of the Acrothoracica adapted to boring habit.

Furthermore downwards within the sac, there is a brush of upward-pointing fine hairs (Fig. 4, *hr*) on the inner surface of the mantle on either side. These hairs also may act as accessory barriers to the foreign intruder.

CHITINOUS SPINES. The external surface of the mantle is furnished with many scale-like ornamentalations, which become obsolete towards the disc and the lower part.

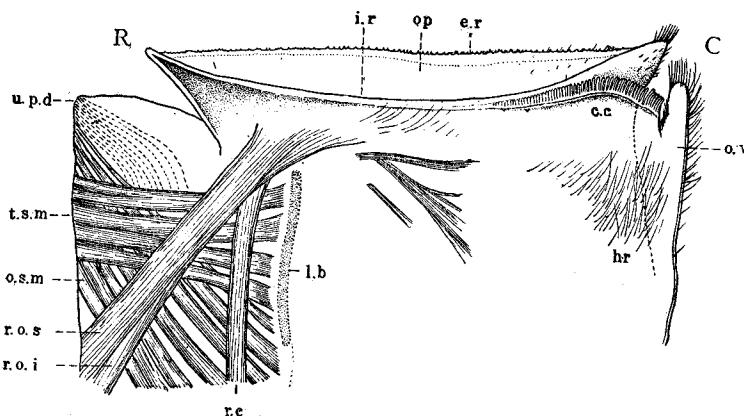


Fig. 4. Upper portion of mantle on the left side, showing the details of operculum and musculature lying towards the attachment-disc, semidiagrammatic, inner view. Lettering as on p. 26. $\times 20$.

Besides, minute chitinous spines (Fig. 5, *sp*) and long hairs (*hr*) are sparsely arranged. These spines are generally directed upwards in the upper part but irregularly in the lower part, and larger towards the operculum, where they measure about $6-15\ \mu$ in length. They are simple, bifid or trifid in shape, but not star-headed as in other Acrothoracicans. They are undoubtedly the agents of excavation, so that they may be moulted and worn away together with the external membrane at each exuviation and excavation.

LATERAL BAR. On each side of the external membrane of the mantle towards the rostral side, there is a peculiar chitinous thickening running downwards at a short distance as a slight strip. It is barely discernible even in full-grown specimens, but when distinct, it is tinted yellowish and as long as 0.5 mm. This strip corresponds to the so-called 'lateral bar' or 'horny bar' called by DARWIN (1854) and the

'Verdickungsleiste' called by BERNDT (1907) found in other Acrothoracicans; in *Cryptophialus* it is unusually developed and specialized in structure. Its position coincides with the line along which the body proper within the mantle cavity is connected with the mantle sac (Fig. 4, *l.b*; Fig. 6, *p.l.b*). Internally there is no structure connected with this bar, but it provides the base of attachment for the short transverse muscles (*t.s.m*) extending towards the edge of the upper part of the attachment-disc.

As to its nature, DARWIN and BERNDT suggest that it serves as a fulcrum for the contraction of the longitudinal muscles and supports the orifice by its elasticity towards the base of attachment. This can not be supported at least in the case of *Berndtia*, as will be discussed in more detail later. In short, it apparently serves as a fulcrum by pressing the mantle against its side wall of the own burrow at each

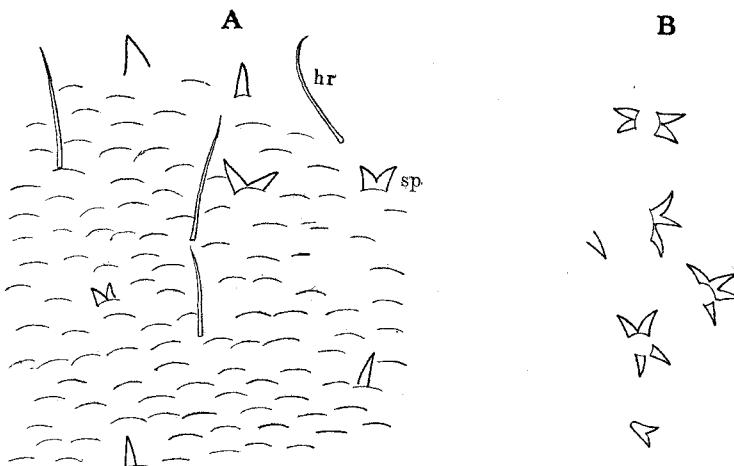


Fig. 5. A, scale-like ornamentation, with hairs (hr) and chitinous spines (sp), seen on the mantle a little below the operculum. $\times 335$. B, various forms of chitinous spines. $\times 420$.

excavation or contraction of the whole mantle. A comparable structure has been found in the Ascothoracican genus *Bacculaureus*, as known as 'chitinous ridge' or 'Chitin-Leiste', though in this case it is not situated on the mantle, but on the sides of the anterior part of the body proper (cf. BRATTSTRÖM, 1956).

ATTACHMENT-DISC. The rostral side of the mantle below the operculum is permanently attached to the wall of the burrow in which the animal is lodged, forming the disc for attachment. In most cases, it does not extend to the lower extremity of the mantle, but often more downwards in fully matured specimens. The upper end of the disc which is supposed to be the initial position of attachment, is strongly produced like a knob (Fig. 4, *u.p.d*), and stands free from the rostral end of the operculum, being inserted a deep notch between.

The disc is apparently flask-shaped or spatulate in outline, gradually tapering

upwards and roundly ended at the base. It is convex outwardly, more in its narrowed upper part than in the rounded lower part. When the animal is carefully removed from the wall of the burrow, it appears that the uninjured upper portion of the disc, about 0.2-0.3 mm in width, is coated with a longitudinal series of small cuticular laminae which become thinner and generally obliterated downwards. This continuous cuticular covering adheres so firmly to the wall that can be hardly detached without damage. The formation of this cuticular laminae, as will be discussed in later papers, reminds one of the act of moulting accompanied by the excavation in the rock-boring pedunculate cirriped *Lithotrya* (DARWIN, 1851; SEWELL, 1926; CANNON, 1935). As in the case of *Lithotrya*, the whole chitinous covering is periodically cast at each moult, fresh laminae taking the place of the old ones worn down by boring. But old ones early attached to the wall remain permanently, so that a series of new laminae periodically added to older ones might be formed there.

The upper projection of the disc is firmly attached to the under side of a roof formed at the rostral end of the slit which is close-fitting to a deep notch below the rostral end of the operculum, so that it is hidden from upper view. This slight roof protruded above the disc is usually overlaid by a calcareous lining more thickly than elsewhere, hence it may mislead to be a product of the animal itself. AURIVILLIUS (1894) states the disc of *Lithoglyptes indicus* to be wholly calcareous, but in my opinion it may be nothing but a calcareous lining secreted only to anchor itself so firmly to its hollow: now it remains, however, to discuss the mechanism by which the secretion of calcium carbonate is taken place.

Body and its Segmentation

GENERAL OUTLINE. As usual in all known Acrothoracicans, the body proper enclosed within the mantle-sac is considerably elongated, tapering posteriorly and curved ventrally near the posterior end like a hook. It is widest at the anterior (or upper) portion, namely the head (Fig. 6, *H*). At rest, when the cirri are withdrawn into the mantle, the body is apparently S-shaped. It is somewhat compressed laterally in the upper portion, while more compressed dorsoventrally in the terminal crooked portion, where 5 pairs of multi-articulate, biramous thoracic appendages of considerable length are situated ventrally (Fig. 6, *c₂-c₆*); these appendages are named 'terminal cirri'.

The upper surface of the head, which corresponds to the frontal side of the labrum in ordinary cirripeds, is very broad, about one-third as long as the operculum, and lies horizontally parallel to the orifice, leaving a narrow interspace below the orifice. At its upper ventral corner forming a right angle, a developed oral cone or mouth (*m*) is situated. Below the mouth there is the first pair of thoracic cirri, usually called 'mouth cirri' (*c₁*) with a long protopodite is situated.

SEGMENTATION OF BODY PROPER. The body consists of a head and a thorax as

in ordinary cirripeds. In all Acrothoracicans, however, it is a very difficult and unsatisfactory problem to determine the line between the head and the succeeding thorax and also to trace the segments of the latter. Thus, the former views on this problem are very divergent, and the problem remains unsettled. In this respect, my observations on this *Berndtia* from a new point of view, though not always convincing,

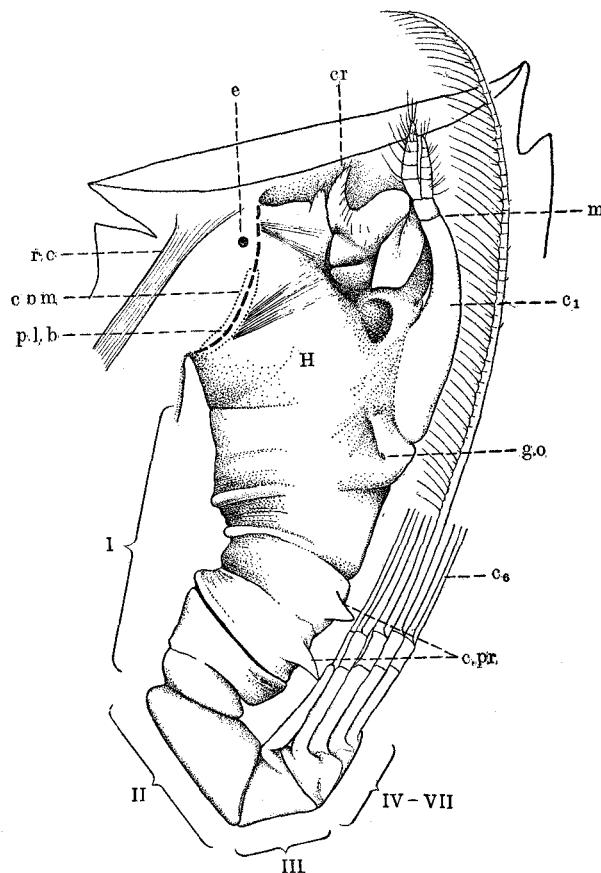


Fig. 6. Body proper within the mantle, showing the segmentation and appendages semidiagrammatically. Roman numerals show the number of thoracic segments. Other lettering as on p. 26. $\times 20$.

may give a more probable interpretation on the segmentation that has been most disputed.

As often pointed out by previous authors, there is no distinct trace of segmentation in the anterior portion of the body without appendages. So it is very problematic to consider some transverse folds, either distinct or indistinct, as the joints between the thoracic segments. Apparently the anterior portion of the body in

Berndtia may be divided into seven regions by six, more or less distinct, transverse folds. These folds are usually found in most examples, but do not completely surround the body, since any distinct introversion of cuticular covering is not formed along them. Therefore, these cannot very well be looked upon as the true segments regulated functionally. I am thus inclined to consider them as the secondary modifications due to the incessant contraction of the body. In another word, it represents rather a functional boundary, for the constitution of the body wall differs from that of the true thorax of ordinary cirripeds. The anterior portion concerned is to be regarded as the prosoma prolonged posteriorly or downwards, instead of a number of thoracic segments fused together. In the following description, for the sake of convenience, I shall use the term 'pseudosomite' for divisions formed on the lengthened prosoma. This is supported by the arrangement of internal musculature which will be described in fuller detail, when the internal anatomy is dealt with.

In ordinary cirripeds, the head is always fused with the first thoracic segment without trace of suture and profoundly expanded like a laterally compressed globe, forming the so-called 'prosoma'. This can be applied to the case of *Acrothoracica* too, though the outline of the prosoma is much elongated as a result of downward-extending growth in relation to the boring action.

A little below the line of connection between the body and mantle, the body is usually more or less inflated on each side, and below this the external membrane is folded transversely. This incomplete fold indicates the line of fusion between the head and the first thoracic segment. The succeeding region close to the head, bearing the mouth-cirri on the ventral side, is somewhat swollen at the base of the cirri, and separated by a more or less distinct transverse fold from the lower region; this region, which I call the first pseudosomite, may correspond to the first thoracic segment called by most of previous authors. A pair of oviducts run transversely along this region underneath and open to the exterior at the base of a slight elevation beneath the mouth-cirri; its opening (*g.o.*) is very minute so that it may be hardly distinguishable from the outside.

In the succeeding regions, the transverse folds of the external membrane become more distinct downwards, and thus it may be divided into five pseudosomites. The second pseudosomite is bare and strongly wrinkled on the dorsal side. The third and fourth ones, which are divided by a slight fold on the dorsal side, but bear each a pair of conical processes (*c.pr.*) on the ventro-lateral side. This conical process reminds one of the "zwei gerundet-konische Höckerpaare wie Zitzen" (AURIVILLIUS, 1894) in *Lithoglyptes indicus*. These processes have been considered the vestige of thoracic appendages by AURIVILLIUS. Most probably, however, as supposed above, they are homologous with the filamentary appendages found in some members of pedunculate cirripeds, such as the families Oxynaspidae, Lepadidae and Poecilasmatidae; their nature has not been confirmed, but they are likewise bare, flexible and structureless, being not supported by any muscle internally.

At the end of the fourth pseudosomite, the body is prominently folded and an

yellowish thick chitin is inserted all along the fold. Internally, a series of anterior longitudinal dorsal muscles and that of posterior longitudinal dorsal muscles are articulated here; details of musculature will be described in later papers. The demarcation between the fifth and sixth pseudosomites is represented by a slight fold.

At the end of the sixth pseudosomite, the body is considerably constricted and then bent ventrally. The succeeding region towards the lower extremity is distinctly segmented and apparently divisible into three segments. By closer examination, however, it may be defined that the last one consists of four segments which became completely fused together. Therefore, the crooked terminal portion of the body is clearly composed of six thoracic segments, namely from the second to the seventh (Fig. 7).

The second segment (Fig. 6, II) is much compressed dorsoventrally and, as seen from the side, subtriangular in outline, and its frontal part of the dorsal wall is usually produced upward into a rounded knob. The succeeding third segment is likewise compressed dorsoventrally, triangular in lateral aspect and shorter than the second; at its narrowest ventral margin a pair of long thoracic cirri are borne. The fourth to seventh segments are, as mentioned above, fused together, but traces of distinct or less distinct sutures are defined on the dorsal side, and each bears a pair of thoracic cirri on the ventral side. The terminal end of the body is formed only of two simple rounded lobes which are divided by a distinct median notch. No caudal appendages can be traced. All these terminal segments are covered with a thick and yellowish cuticular membrane, and colored purplish as in the operculum and upper portion of the head (Fig. 7).

Oral cone and Mouth-parts

ORAL CONE. As usual in the *Acrothoracica*, the oral cone or mouth is very developed for the size of the body itself and consists of buccal appendages of ordinary type, though peculiar in every part. Unlike that of ordinary cirripeds, the mouth is not probosciformed and situated near the orifice at the anteroventral corner of the head, so that the upper surface of the labrum is perpendicular to the outer maxillae.

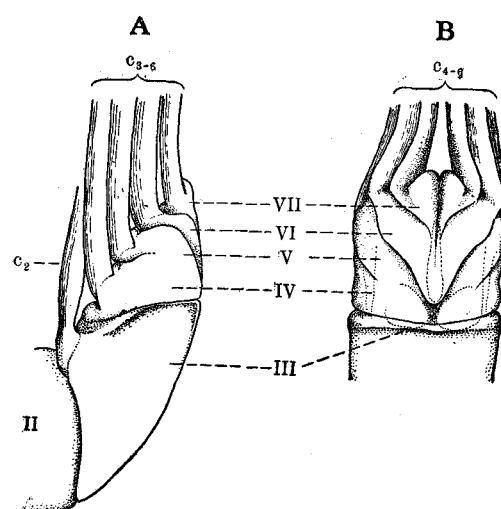


Fig. 7. Terminal portion of body, showing the fused thoracic segments carrying the cirri respectively. A. lateral view. B. dorsal view. Roman numerals show the number of thoracic segments. Other lettering as on p. 26. $\times 55$.

Before describing the mouth-parts, it is to be noted that there is a peculiar crest-like projection (Fig. 6, *cr*) in front of the labrum. It is bullate, obtusely pointed and curved backwards. Such a projection is not mentioned for *Lithoglyptes*, but reminds one of 'a little knob' in front of the so-called 'lancet-shaped labrum' or 'Labrumzapfen' of *Cryptophialus*. This seems homologically to be a prolongation of the fronto-basal part of the labrum, where it is a little swollen only in most of the Lapadidae.

The mouth consists of a labrum and four pairs of mandibular palpi, mandibles, maxillae I and maxillae II. These organs show a close resemblance to those of *Lithoglyptes indicus* figured by AURIVILLIUS (1894) and BROCH (1931). Concerning their affinity, BROCH suggests a closer resemblance to Lapadidae s. str., while KRÜGER (1940) to Balanidae. In my opinion, however, these, as in *Lithoglyptes*, exhibit a striking likeness with those of *Ibla*, a pedunculate cirriped living usually attached to the peduncle of another littoral cirriped *Mitella*.

LABRUM. The labrum itself is bullate. Its inner edge is semicircular in outline and furnished with a row of feeble teeth throughout. The surrounding part is broadly expanded and somewhat pointed at the median distal end, and planted sparsely with hairs.

PALPI. The palpi (Fig. 8, E) are attached, on each side, to the lateral edges of the base of labrum and project upwards. They are elongate, tapering, flattened and fringed with stiff hairs at the distal end and along the inner edge. Seen from the ventral side, the inner edge bearing hairs seems to face upwards and towards the side opposite to the mouth owing to its distortion. In every ordinary cirriped, however, the corresponding edges on both sides are directed inwards and face to each other across the mouth-opening under the labrum. This may be caused by the fact that the mouth is, in all Acrothoracicans, situated closely below the mantle opening and thus directly exposed to water pouring into the mantle cavity. The similar feature has been noticed by DARWIN in *Cryptophialus*, but he did not explain why it is so.

MANDIBLES. The mandibles (Fig. 8, A-B) are very developed and powerful. The free edge is provided with 3 or 4 strong teeth and a pectinated lower angle; the teeth on both sides are usually asymmetrical in number. The uppermost one of the teeth is strongest and widely separated from the second. The upper edge of the blade is devoid of hairs but the lower edge and the lower half of the lateral surfaces are clothed with hairs.

MAXILLAE I. The maxillae I (Fig. 8, C) are furnished with 2 strong and 1 or 2 shorter spines above a very broad notch lying in the middle of the free edge. Below the notch about 10 spines of similar size but shorter than the upper two, occur on the median part, and about 5 much shorter ones on the lower part. Around the free edge only the lateral surface is densely hairy. At the lower edge near the proximal end, a very long, rigid apodeme is attached.

MAXILLAE II. The maxillae II (Fig. 8, D) are remarkably developed and largest; they stand erect and altogether cover the whole opening below the labrum. Each blade is a simple, elongate, much swollen and trihedral lobe, with a slight notch indicating the suture between the upper and lower segments fused together in the middle of the inner surface. The outer surface of the upper segment is rounded and

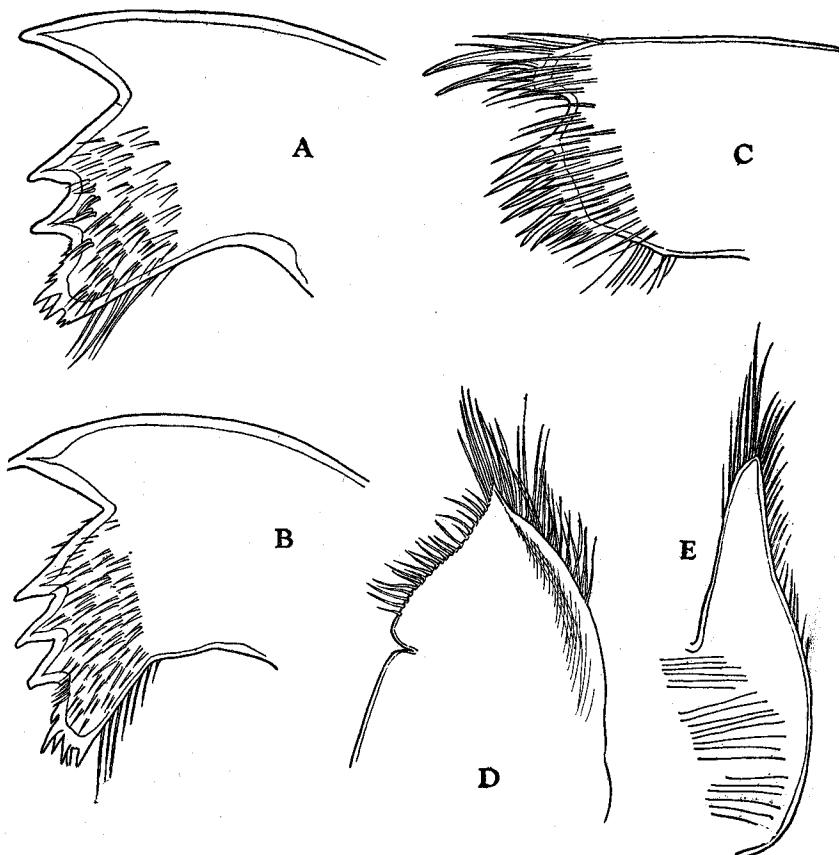


Fig. 8. Mouth-parts. A, B, mandible. C, maxilla I. D, maxilla II. E, mandibular palp. A-C, $\times 150$; D, E, $\times 80$.

densely covered with long hairs, while the inner surface forms a sharp ridge fringed with shorter hairs. The tip is sharply pointed and slightly incurved. The lower segment is very broad and devoid of hairs at all.

Cirri

The thoracic appendages consist of the first oral and the second to sixth terminal cirri, all of which are borne on the ventral side. Each of the cirri bears, as usual in ordinary cirripeds, two multi-articulate rami and a protopodite formed of two

segments. The bases of the cirri on both sides are in close contact with each other along the medial line of the ventral wall.

MOUTH-CIRRI. The first pair, as usually called the 'mouth-cirri' (Fig. 6, *c₁*), is closely approximated to the mouth and widely separated from the remaining cirri which are crowded together at the terminal end of the body. The protopodite is very prolonged and proceeds upwards in contact with the ventral surface of the head, nearly extending to the distal angle of the labrum. Its lower segment is very bullate and thickly clothed with fine hairs anteriorly, while the upper segment is very short, not over one-fifth of the length of the lower one, and unhaired. The two rami on the protopodite are also short, about one-fourth to one-fifth as long as the protopodite; the anterior ramus is a little longer and wider than the posterior and usually curved backwards. Both rami are distinctly segmented and thickly clothed with fine long bristles and plumose like a feather.

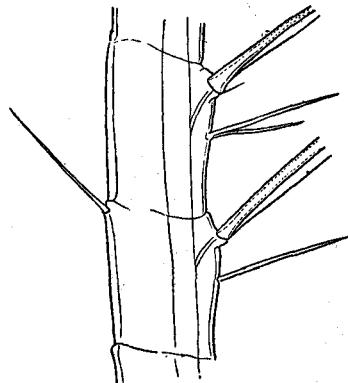


Fig. 9. Two segments of terminal cirri. $\times 210$.

TERMINAL CIRRI. The five pairs of the thoracic cirri at the terminal part of the body, namely the terminal cirri (Fig. 6, *c₂₋₆*), are almost exactly alike, excepting that the second pair is a little shorter than the succeeding pairs. In all these cirri, the protopodite is comparatively slender and consists of two segments of which the lower segment is about thrice as long as the upper one, both carrying fine hairs ventrally. The rami are more or less distinctly segmented, being only defined by the manner of arrangement of bristles on the ventral side. Each segment, when it is distinct, bears a paired longer and a paired or single shorter

bristles on the ventral side and a single short bristle at the dorsal distal angle (Fig. 9).

In most cases, the posterior ramus is a little longer than the anterior in the third to sixth cirri, while a little shorter in the second cirri. For comparison the number of segments with the length of each ramus in a specimen dissected (5-6 mm long and 3 mm wide) is given below:

	Mouth-cirri		Terminal cirri					
	I	II	III	IV	V	VI		
Total length (in mm)	1.65	1.48	3.45	2.5	4.1	4.65	5.35	5.65
Number of segments	6	5	26	16	36	46	47	56
Length of protopodite (in mm)			1.2	1.1	0.9		1.0	1.0
								1.1

a: Anterior ramus. p: Posterior ramus.

Cirral Movement and Feeding Habit

CIRRAL MOVEMENT. In connection with describing the external morphology, some observations on the cirral movement which I have made on living specimens in the laboratory should be mentioned. The cirral movement and the method of food-seizure in ordinary cirripeds have been studied by some authors since DARWIN. As to the Acrothoracicans, the works of AURIVILLIUS (1894), BERNDT (1903), GENTHE (1905) and NILSSON-CANTELL (1921) on *Trypetesa lampas* since the classical work of DARWIN are only known. The last-named author has published a concise summary of the process in detail.

As far as my observation goes on, the cirral movement of *Berndtia* seems quite different from that of *Trypetesa lampas*. In ordinary cirripeds living in the littoral, such as *Balanus balanoides*, *B. crenatus* and *B. balanus*, the feeding habit as a whole may be summarized as follows:—

“Die *Balanus*-Arten sind durch lebhafte Bewegungen ausgezeichnet; alle Cirren und Rami werden gleichzeitig in der Weise bewegt, dass die Cirren zuerst ausgestreckt und dann auf einmal gegen den Mund zu gebogen werden, wobei sich der Körper zugleich etwas in die Schale senkt. Die Bewegungen können, besonders bei kleineren Exemplaren, außerordentlich lebhaft sein. So konnte ich z. B. bei 1-2 mm grossen Exemplaren bis 140 Schwingungen in einer Minute zählen. Diese Bewegungen werden während eines grossen, und besonders der dunkleren Teiles des Tages ausgeführt. Ziemlich wahrscheinlich erscheint GRUVELS Vermutung, dass diese Bewegungen nicht allein den Nahrungsfang zum Zwecke hätten, sondern auch die Aufgabe besäßen, das Wasser der Mantelhöhle zu erneuern und zur Zirkulation des Blutes im Körper beizutragen.....Für *Balanus* ist somit charakteristisch, dass sich die Cirren *nicht unabhängig* voreinander, sondern *gleichzeitig* bewegen” (after NILSSON-CANTELL, 1921, p. 78).

In comparison with the above comment, the feeding habit of *Berndtia* is of great interest, because the body itself does not protrude out of the orifice even if the terminal cirri are fully stretched. In any time the animal at first uplifts the posterior (carinal) side of the whole mantle a little above the entrance of its burrow until the cirri begin to move. The anterior (rostral) end of the operculum is simultaneously uplifted as well, but very slightly. Such a posture is kept continuously during the time of cirral movement as it is. In normal and most favourable condition, all terminal cirri are perfectly protruded out of the orifice, and expanded fully in a fan-like shape, as shown schematically in Fig. 10.

When viewed from the above, the rami of the fourth to sixth pairs are set apart from each other in the same cirri and close to the adjoining rami of the different cirri. The third pair of the cirri is a little separated from the fourth and more widely from the second, and then somewhat occupies the lateral position, if considering the whole in such an expanded state as a ‘casting-net’ (after CALMAN, 1909, p 114). The rami of the second pair representing the lower portion of a net are

protruded horizontally, as lying a little above the operculum. When the net is cast out, the cirri are not coiled up independently, excepting only that the second pair can bend a little inwards. All the rami do not move independently but simultaneously, as is the case with those in ordinary cirripeds living in the littoral.

In most cases, the cirri do not keep the stretched state for a long time, but at times rotate about an axis as they are stretched. But they are, as usual, soon withdrawn altogether into the mantle cavity without coiling up as they are fully stretched. This casting movement, much like that of other coral-inhabiting cirripeds (*Creusia* and *Pyrgoma*) lodged on the same coral colony, is repeated rhythmically about 24-25 times per minute, but often interrupted with short or long irregular pauses. It is thus not so vigorous as in other ordinary cirripeds as well as *Trypetesa*. The greater the animal weakens owing to a longtime culture in aquaria, the more irregular the

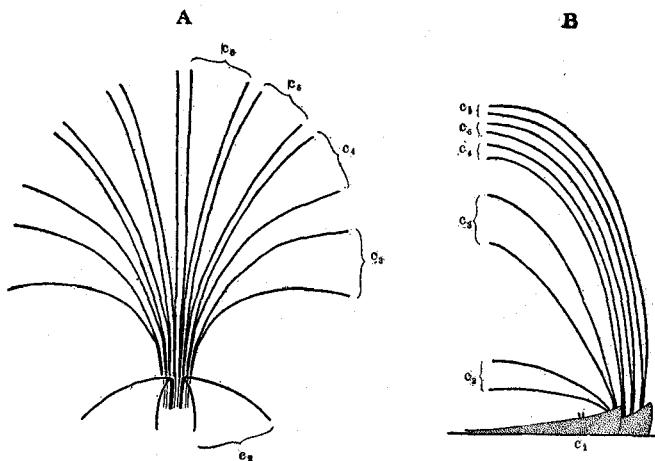


Fig. 10. Diagram showing the fully stretched state of cirri forming a 'casting-net'. A, frontal view. B, lateral view. Lettering as on p. 26.

cirral movement becomes and the pause lasts for a very long time. Hence the rate of pulsation seems considerably variable in individuals.

SENSITIVITY. The sensitivity of the cirri in the *Acrothoracica* to any stimulus is very little known, with only a brief note by GENTHE for *Trypetesa*, that is, "To a light touch the animal usually, but by no means always, responds by ceasing the rhythmical movements and often contracting the mantle lips besides." *Berndtia* is very sensitive to an appropriate decrease of illumination, though not always, as is also the case with most of the *Balanus*-species (COLE, 1929, 1932). This evidently depends upon the reaction of the unusually developed eyes which are embedded in the connective tissue under the operculum but resplendent through the epidermis.

If a shadow is cast on the animal, the cirri are quickly withdrawn into the mantle cavity, and the operculum is closed. But soon they are protruded and extended

fully. To stronger stimuli the animal responds by an immediate retraction of the cirri and withdrawal of the whole body into its burrow. The length of the period of retraction following a decrease of illumination depends upon the degree of the decrease. To an increase of illumination, however, there is no remarkable response as such.

The response of the cirral movement to the tidal or diurnal rhythm could not be observed. But from its natural habitat it seems probable that there is no remarkable regularity between them.

FEEDING MECHANISM. It is undoubtedly that the above-mentioned rhythmical movement of the cirri produces an inflow of water current. The current, on one hand, carries food particles into the mouth, and on the other renews the water in the mantle cavity and serves for the respiration as well as the circulation of brood. As has been stated above, the 'casting net' for capturing food which is formed of the expanded five terminal cirri, is always directed towards the rostral side, instead of being upwards as usual in the Balanidae (cf. Fig. 10, B). When food particles are carried in front of the net, the terminal cirri are used together for capturing them, but their duties seem to be separate from one another. The second cirri alone can work independently, though not always.

When a food first touches the back portion of the net which is formed of the close-set three pairs of the cirri (IV-VI), it is kept in the middle of the net by the third cirri of both sides from escapement, and then caught by the second cirri at the bottom of the net. Then the food is eventually conveyed to the mantle cavity by the following retraction of all the cirri. When the cirri are perfectly retracted, the thorax is a little pushed forwards and contracts at the same time. In this connection it is to be noted that the second cirri are set apart from the remaining cirri and expand themselves, so that the rami are almost perpendicular to the lower parts of the other cirri and lying in a plane parallel to the surface of the operculum. In this position it is easier for its relatively shortness to other cirri to seizure food. So it seems probable that although these five pairs of the terminal cirri are morphologically almost alike, the first one (really the second thoracic cirri) functionally corresponds to the anterior three pairs of shorter cirri in the Balanomorph Cirripedia, whereas the remaining four to the posterior three pairs of longer cirri.

FOOD. Regarding the food of *Trypetesa lampas* which burrows itself into the gastropod-shells inhabited by hermit-crabs, GENTHE states that "It evidently feeds on very finely distributed organic matters, be that fine particles which pass into the water when the crab cuts and prepares its food, be that faecal matter." The same may be said for the present animal.

On examination of the contents of the digestive canal in both fresh and preserved materials, I took in vain to find any trace of corporal matter, as they were invariably filled with brown slimy substances. This may be due to the probable rapidness of digestion, provided that they can prey any planktonic organism. However, this

animal, as well as other Acrothoracicans, is too small to take wholly the planktonic organisms of a relatively small size, since its mantle opening is less than 1 mm in diameter. It is thus probable that all the Acrothoracicans feed upon minute organisms or any organic debris alone floating in water, as large as passing into the orifice. The food in this species may be afforded also by the host corals as remnants of their own animal foods or as debris of vegetable matter which is invariably refused by the coral.

On one occasion I happened to observe that the outer cuticular exuviae of its own cast off after moulting are subject to be eaten by the host coral.

SWEEPING MECHANISM. The foregoing description does not apply to the mouth-cirri. These are not only separated by a wide space from the remaining cirri which are crowded together at the posterior end of the body (cf. Fig. 11), but their constitution considerably differs from the latter

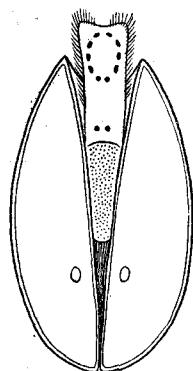


Fig. 11. Diagram of operculum showing the position of cirri, when the orifice is opened. Black points show the position of cirri and two open spots in the operculum the position of eyes.

According to NILSSON-CANTELL (1921), the respiratory current in *Trypetesa* constantly circulates in the mantle cavity, passing through the slit-like opening which is divided into two partitions, inherent and exharent. He says that "Partikeln wurden in diesem (unteren oder rostralen) Teil des Capitulum eingeführt, zogen am Munde und den Mundcirren, an denen einige hängen blieben, wobei bis zum carinalen Teil der Mantelhöhle, wo sie der austretende Strom ergriff und durch den Oberen Teil der Öffnung aus der Mantelhöhle hinausleitete. Für das Einströmen haben die Bewegungen der Mundcirren, für das Ausströmen jene der hinteren Cirren die grösste Bedeutung."

From his statement it seems clear that the mouth-cirri in *Trypetesa* play an important rôle in the seizure of food, although they have been considered by former authors as acting as brushes for sweeping. Moreover, the peculiar bands of stiff bristles on both sides in front of the mouth appear probably

act as an efficient sieve for capturing food and at the same time as a hedge, barring the ingress of any harmful intruder into the sac, as was supposed by GENTHE. Such band of bristles does not occur in any other genera of the Acrothoracica and in ordinary cirripeds; apparently it answers functionally to the net forming of terminal cirri in other Acrothoracicans as well as ordinary cirripeds. These peculiarities in function as well as structure are probably correlated with the unusual modification of the body proper, in particular as to the reduction of the thorax and thoracic cirri, as the terminal cirri cannot be protruded outside. In all other Acrothoracicans, however, the terminal cirri can be protruded altogether.

In *Berndtia*, on the other hand, the current within the mantle cavity seems to be

reversible along the same tract near the carinal side in accordance with the extension and contraction of the body itself together with the terminal cirri. When the terminal cirri are fully protruded, the mouth-cirri are also stretched upwards, but only slightly protruded beyond the orifice (cf. Fig. 10B, c_1). Therefore the mouth-cirri are not concerned wholly with the terminal cirri functionally, but solely act as brooms, sweeping around the orifice.

Namely, the carinal half of the orifice, through which the terminal cirri are exserted, is swept by the terminal brush of the rami of the mouth-cirri, which can bend towards the carinal side only, even when the terminal cirri are not exserted. It can quite clearly be seen by observing on the living animals and be proved by dissection for the examination of the internal structure. Any harmful object intruding from outside is eventually prevented by the comb-collar around the margin of the orifice, together with brushes of fine hairs a little below the orifice, all being pointing upwards.

In addition, it seems probable that mucus, which is secreted by the host coral in large quantities, plays an important part in entangling the silt or calcareous detritus cast down during the process of excavation, and then in cleaning the orifice. The sweeping movement is further aided by water current in the circumferences. In a most specialized Acrothoracican, *Cryptophialus*, on the other hand, the so-called lancet-shaped labrum, which became modified into an unusually prolonged movable organ because of the reduction of the mouth-cirri, may play a similar part to the mouth-cirri of *Berndtia* as well as other Acrothoracicans.

Anyhow, the sweeping movement as stated above appears to be a specialized function in the group of Acrothoracica, that is closely correlated with the feeding habit. It is undoubtedly a physiological phenomenon adapted to the burrowing mode of life.

Summary

1. The investigations on the boring cirripeds, Acrothoracica, with special reference to the two species, *Berndtia purpurea* and *Balanodytes taiwanus* which were recently described as new representatives by myself, are published in a series of papers. This paper, forming the first part of the series, deals only with the biology and external morphology of the female of the former species.

2. *Berndtia purpurea* is invariably found boring in the living part of the two reef corals, *Leptastrea purpurea* (DANA) and *Psammocora profundacella* GARDINER, and none in other corals.

3. It is distributed mainly on the Pacific coast of southern Japan, but may range further southwards to Formosa and Micronesia. Only an exceptional example was found, that is, a specimen of *Podabacia crustacea* (PALLAS) from Singapore heavily infected by an Acrothoracican borer like *Berndtia*.

4. When alive, the mantle-lips forming together an operculum, which is close-

fitting to the slit of burrow, are marked with two distinct bands of violet-blue patterns, which anteriorly with a golden glistening body (eye) on each side.

5. The orifice between the mantle-lips is hinged at the rostral end, while its carinal end forms a flexible velum folded outwards, serving to open and close the orifice.

6. A little below the operculum, the lateral sides of the orifice are fringed with a comb-like row of flattened setae, acting as a barrier to prevent foreign harmful intruders. This is a specialized structure peculiar to the Acrothoracica adapted to its burrowing life.

7. The 'lateral bar' situated close to the attachment-disc is nothing but a chitinous thickening of the external membrane, which serves as a fulcrum at each excavation or contraction of the mantle.

8. The 'attachment-disc' is flask-shaped in outline and at its upper portion forms a continuous series of cuticular laminae which remain at each moult, as they are not cast off with other exuviae.

9. The body within the mantle-sac consists of a large head and seven thoracic segments tapering posteriorly. The anterior portion of the thorax fused with the head, namely, the 'prosoma' is much prolonged and differentiated into 6 'pseudosomites' by transverse folds, whereas the posterior crooked portion is distinctly segmented and its last one clearly represents four thoracic segments fused together with traces of articulations.

10. Two 'conical processes' found on the ventrolateral sides of the prolonged prosoma seem probably homologous with the filamentary appendages in some genera of ordinary cirripeds, instead of being vestiges of the cirri.

11. The cirri consist of one pair of the 'mouth-cirri' and five pairs of the 'terminal cirri'. The mouth-cirri may act as brooms to sweep around the orifice and the terminal cirri serve mainly for the seizure of food by forming a 'casting net'.

REFERENCES

AURIVILLIUS, C. W. S. 1894. Studien über Cirripeden. Kungl. Sv. Vetensk. Akad. Handl., Bd. 26, no. 7, pp. 1-107, pls. 1-9.

BERNDT, W. 1903. Zur Biologie und Anatomie von *Alcippe lampas* Hancock. Inaug. Diss., Univ. Berlin (1902); Zeitsch. wiss. Zool., Bd. 74, Ht. 3, pp. 396-457.

— 1907. Studien an bohrenden Cirripedien (Ordnung Acrothoracica Gruvel, Abdominalia Darwin). I. Teil: Die Cryptophialidae. Arch. Biontol., Bd. 1, pp. 167-210, pls. 14-17.

BRATTSTRÖM, H. 1956. On the organization of the genus *Baccalareus* (Ascothoracica) with description of a new South African species. In: Bertil Hanström, Zool. Papers in honour of his 65th birthday (Edited by K. G. Wingstrand), pp. 106-119. Lund.

BROCH, Hj. 1931. Papers from Dr. Th. Mortensen's Pacific Expedition 1914-16. LVI. Indomalayan Cirripedia. Vidensk. Medd. Dansk naturh. Foren., Bd. 91, pp. 1-146.

CALMAN, W. T. 1909. The Cirripedia. In: A treatise on zoology (Edited by R. Lankester), Pt. 7, Fasc. 3, Crustacea, pp. 106-142. London.

CANNON, H. G. 1935. On the rock-boring barnacle, *Lithotrya valentiana*. Sci. Rep. Gt. Barrier Reef Exped. 1928-1929, Vol. 5, no. 1, pp. 1-17, pls. 1-2.

CANNON, H. G. 1947. On the anatomy of the pedunculate barnacle *Lithotrya*. Phil. Trans. Roy. Soc. London, Ser. B, Biol. Sci., Vol. 233, no. 595, pp. 89-136.

COLE, W. H. 1929. The relation between temperature and pedal rhythm of *Balanus*. Journ. gen. Physiol., Vol. 12, pp. 599-608.

— 1932. The sensitivity of the cirri and the variability of their movements in the barnacles *Balanus tintinnabulum* and *B. balanoides*. Journ. Exper. Zoöl., Vol. 63, pp. 143-153.

DARWIN, Ch. 1851. A monograph on the sub-class Cirripedia. The Lepadidae. London. xii+400 pp., 10 pls.

— 1854. A monograph on the sub-class Cirripedia. The Balanidae, the Verrucidae, etc. London. viii+684 pp., 30 pls.

GENTHE, K. W. 1905. Some notes on *Alcippe lampas* (Hanc.) and its occurrence on the American Atlantic shore. Zool. Jahrb. Abt. Anat., Bd. 21, Ht. 2, pp. 181-200.

HIRO, F. 1937. Occurrence of an acrothoracican cirriped in Japan. Zool. Mag. (Tokyo), Vol. 49, no. 3/4, pp. 135-136. (In Japanese)

— 1938. Studies on the animals inhabiting reef corals, II. Cirripeds of the genera *Creusia* and *Pyrgoma*. Palao Trop. Biol. Sta. Stud., Vol. 1, no. 3, pp. 391-416.

KRÜGER, P. 1940. Cirripedia. Bronns Klassen und Ordnungen des Tierreichs, Bd. 5, Abt. 1, Buch 3, Teil 3. Leipzig. 560 pp.

MA, T. Y. H. 1937. On the growth rate of reef corals and its relation to sea water temperature. Mem. Nation. Inst. Zool. Bot., Acad. Sinica, No. 1, Text, 226 pp.; 100 pls. Nanking.

NILSSON-CANTELL, C.-A. 1921. Cirripeden-Studien. Zur Kenntnis der Biologie, Anatomie und Systematik dieser Gruppe. Zool. Bidr. fr. Uppsala, Bd. 7, pp. 75-390, pls. 1-3.

SEWELL, R. B. S. 1926. A study of *Lithotrya nicobarica* Reinhardt. Rec. Ind. Mus., Vol. 28, pt. 4, pp. 269-330.

Tomlinson, J. T. 1953. A burrowing barnacle of the genus *Trypetesa* (order Acrothoracica). Journ. Wash. Acad. Sci., Vol. 43, no. 11, pp. 373-381.

UTINOMI, H. 1950a. A new remarkable coral-inhabiting Acrothoracican cirriped. Mem. Coll. Sci. Univ. Kyoto, Ser. B, Vol. 19, no. 3, pp. 83-89, pl. 1.

— 1950b. On another form of Acrothoracica, newly found from Formosa. *Ibid.*, Vol. 19, no. 3, pp. 91-96.

— 1950c. General account of the Acrothoracica. In: Some problems of modern biology (Compiled by K. Nakamura), pp. 428-461. Osaka. (In Japanese)

YABE, H., SUGIYAMA, T. and M. EGUCHI 1936. Recent reef-building corals from Japan and the South Sea Islands under the Japanese mandate. I. Sci. Rep. Tōhoku Imp. Univ., 2nd ser. (Geol.), Spec. Vol. 1, pp. 1-66, pls. 1-59.

EXPLANATION OF PLATES I-II

PLATE I

Fig. 1. Colored drawing from life of a female of *Berndtia purpurea* UTINOMI, buried between three polyps of the coral *Leptastrea purpurea* (DANA), upper view. $\times 16$.

Fig. 2. The same freed from its burrow, lateral view. $\times 16$.

Fig. 3. The same buried within its burrow, with partially protruded cirri, carinal view. $\times 16$. (All H. UTINOMI del.)

PLATE II

Fig. 1. A specimen of the coral *Psammocora profundacella* GARDINER heavily infected by *Berndtia purpurea* UTINOMI. $\times 1$.

Fig. 2. A section of a densely infected specimen of *Leptastrea purpurea* (DANA). $\times 1$.

Fig. 3. A specimen of densely infected *Leptastrea purpurea* (DANA). $\times 1$.

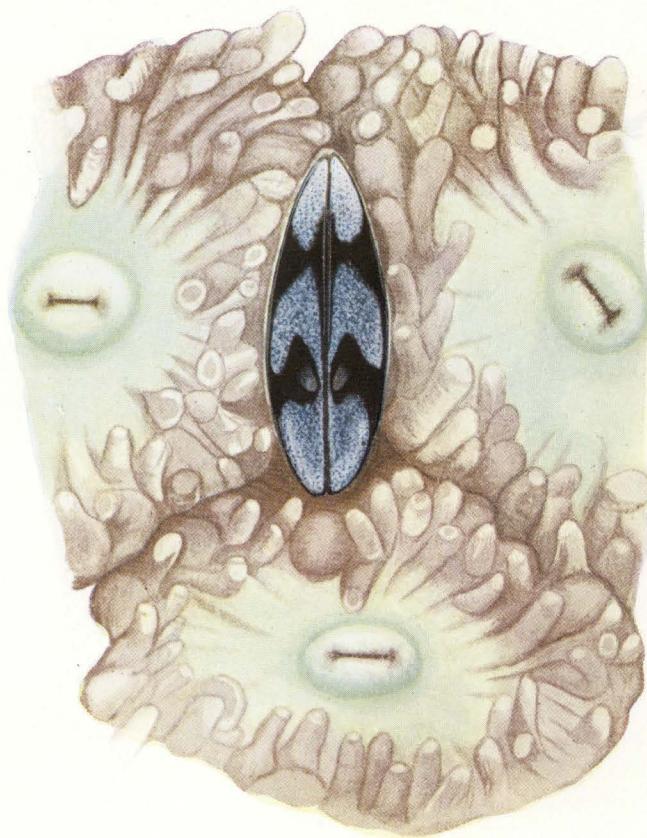
Fig. 4. Slits of burrows found on *Leptastrea purpurea* (DANA), highly enlarged. $\times 3$.

(Scale at 3 applies to figs. 1-3 and scale at 4 only to fig. 4.)

LIST OF ABBREVIATIONS USED IN THE TEXT-FIGURES

C	Carinal (ventral) side.	o.s.m	Outer oblique muscle for supporting mantle-sac.
c ₁	Mouth-cirri.	o.v	Orificial velum.
c ₂₋₆	Terminal cirri.	op	Operculum.
c ₁₋₆	Cirri I-VI.	or	Orifice.
c.b.m	Connecting line between body proper and mantle.	p.l.b	Position of lateral bar.
c.c	Comb-collar.	R	Rostral (dorsal) side.
c.pr	Conical process.	r.c	Retractor corporis.
cr	Crest-like projection.	r.o	Retractor orificii.
e	Eye.	r.o.i	Retractor orificii inferior.
e.r	External ridge of operculum.	r.o.s	Retractor orificii superior.
g.o	Genital opening.	sp	Chitinous spine.
H, h	Head.	t.s.m	Inner transverse muscle for supporting mantle-sac.
hr	Hair.	u.h	Upper surface of head.
i.r	Internal ridge of operculum.	u.p.d	Upper projection of attachment-disc
l.b	Lateral bar.	v.p	Violet-colored pattern.
m	Mouth.		

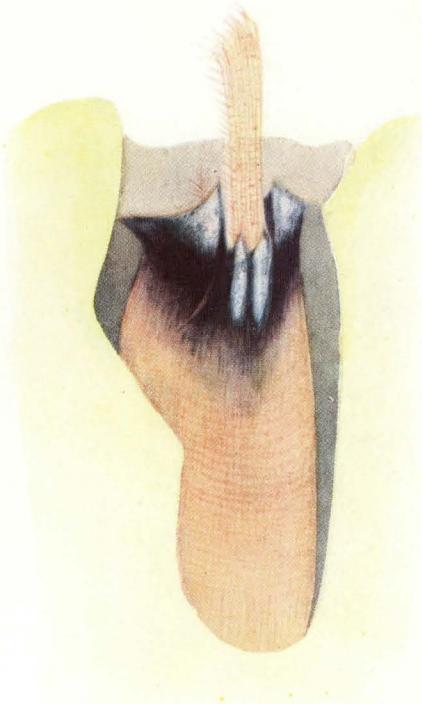
1



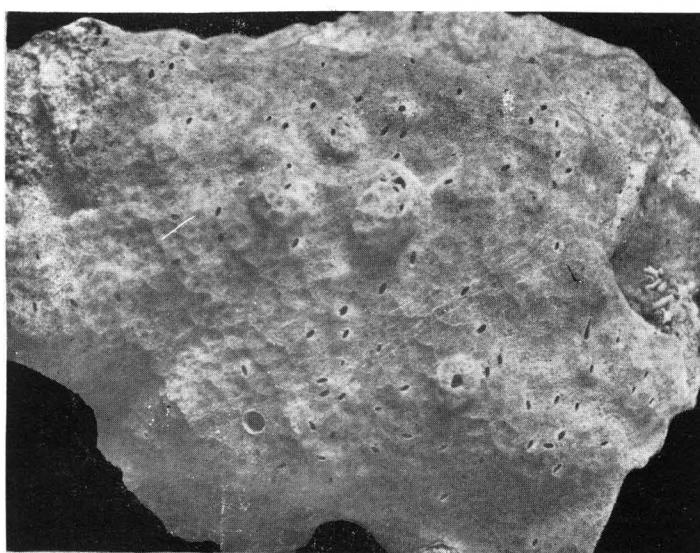
2



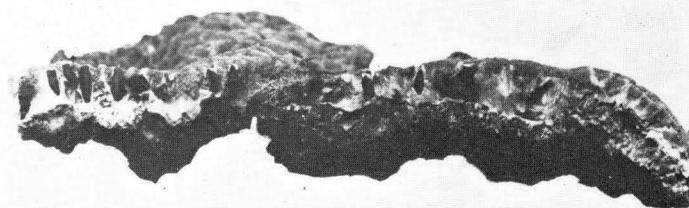
3



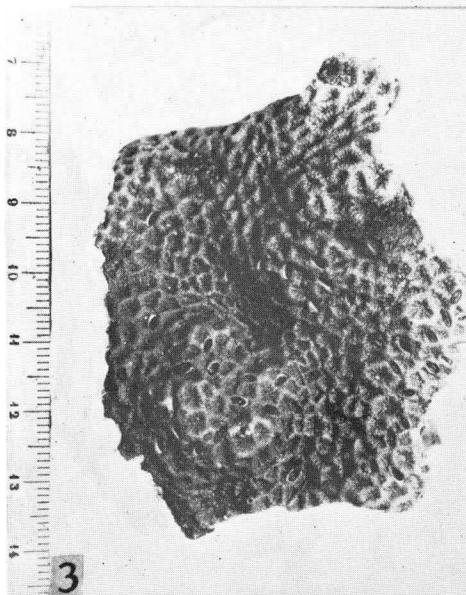
1



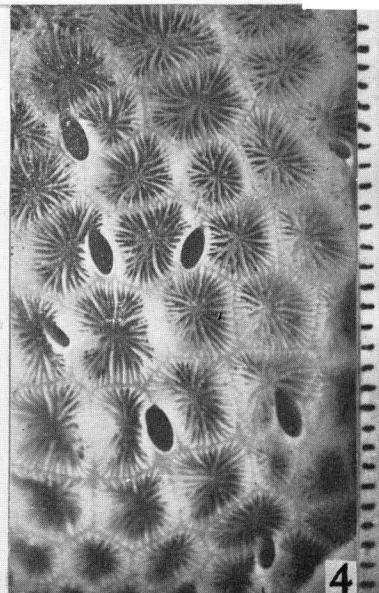
2



3



4



H. UTINOMI: STUDIES ON THE CIRRIPEDIA ACROTHORACICA, I.